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BRL

MEASUREMENTS OF RANGE, DEFLECTION, TIME OF FLIGHT, AND HEIGHT OF BURST FOR FIRED ARTILLERY SHELL METHOD I - TRIANGULATION

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U.S. ARMY LABORATORY COMMAND

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Triangulation, the means by which test range measurements are converted into measurements of range, deflection, height of burst, and time of flight for a fired artillery shell, is explained. This is done by describing the engineering and mathematics behind the technique as currently practiced on today's proving grounds and, also, by discussing the associated accuracy. An alternative to triangulation is suggested under certain circumstances.

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The author would like to thank the many people of the Combat Systems Test Activity (CSTA) who gave me assistance in my quest to understand triangulation - namely, Mr. Leo Heppner, Mr. Dennis Flaherty, Mrs. Agnes Kodat, Mr. Jack, and Mr. Don Gilbert. Also, my reviewers, Messrs. Jim Matts, Robert McCoy, and Dr. Gene Cooper, were very helpful in their comments and suggestions.

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1. INTRODUCTION

Test range measurements for fired artillery shells are of great importance to ballisticians, members of the scientific community who study the motion of artillery projectiles and missiles. The accuracy of aiming data developed by ballisticians can only be expected to be as good as the accuracy of test range measurements taken at a proving ground. It follows that an understanding as to how measurements of range, deflection, time of flight, and height of burst for a fired artillery shell are obtained should be of value to the ballistician. Actually, such knowledge would benefit any weapon systems engineer who must make decisions either directly or indirectly by depending on the use of aiming data.

This report will deal with the actual engineering upon which triangulation is based, as well as the analytical and mathematical procedures by which observer measurements are converted into measurements of range, deflection, height of burst, and time of flight. It is designed to give an individual an introduction to the triangulation technique. However, a copy of the triangulation analytical computer program is included (Appendix B), as well as sample data input (Appendix C) and corresponding data output (Appendix D). This will also allow one to study triangulation in as much detail as desired.

2. THE OPERATIONAL ASPECTS OF TRIANGULATION

Suppose one wants to obtain test range measurements for a M483A1 projectile fired at a quadrant elevation of 950 mils from a M198 howitzer using a particular charge. Also, suppose that one wants the projectile to burst at a height of approximately 200 meters above ground.

The first step is to estimate how far the projectile will fly and to determine the fuze setting required to obtain the desired height of burst. From a tabular firing table or field computer, the test engineer will determine approximate range, deflection (drift), and fuze-setting-to-burst values. Then, knowing the position coordinates of the howitzer and its azimuth of fire from survey, the test engineer will have an idea as to where down range the projectile can be expected to burst.

Accordingly, up to four observers are stationed in towers most opportune in location to the expected burst and impact areas. From survey, the location and heights of the towers are known. Each tower observer will make use of an instrument called a modified transit, which is a transit equipped with a monocular lens with crosshairs that magnifies and has a wide field of view. With this instrument each observer can measure azimuth and elevation angular values with respect to the tower after sighting the burst event through the monocular lens.

During the shoot, each observer will be in radio contact with the gun. Thus, upon firing, each observer will know when to start his stopwatch and will know when to expect burst or impact. Whenever video is not used, it is customarily the responsibility of the observer to obtain time of flight of the round fired as well as angular measurements to burst or impact.

In a test situation, practice rounds called spotters are usually shot first so that it becomes relatively certain that each observer will be successful in obtaining all measurements for the actual firing of the round.

It follows from the engineering behind triangulation that the test range measurements obtained for a fired projectile are as follows:

1) tower locations and heights

2) azimuth, elevation, and time of flight measurements from each tower

3) location and azimuth of gun.

The test range measurements obtained above must be converted into range, deflection, height of burst, and average time of flight. The next section of this report will show how mathematical procedures can be used to do this.

3. TRIANGULATION

Triangulation is the analytical mathematical procedure for obtaining ranges, deflections, heights of burst, and time of flights for fired projectiles from raw test range data. For an air burst round, one first wants to compute the range and deflection from the gun point to the perpendicular projection of the air burst point to the ground ("impact point"). The range is the distance from the weapon to the perpendicular projected point on the ground and the deflection is the angular and linear distance from the weapon line-of-fire to the same point.

"Impact points" are computed from azimuth readings taken from one, two, three, or four towers. There are four modes of computing impacts - one for each tower combination.

For one tower, the "impact point" is determined by the intersection of the gun azimuth and tower azimuth. On the computer output, the deflection will be dashes. The range is the distance from the point of intersection to the weapon position (Figure 1).

For two towers, the "impact point" is determined by intersecting both tower azimuths. Range is defined as above. Deflection from line-of-fire is computed as a perpendicular distance from "impact" to the line-of-fire and as an angle between the line-of-fire and vector from weapon to "impact point" (Figure 2).

For three towers, the "impact point" is computed as the average of three intersection points of the three azimuth readings with the restriction that the area of the triangle determined by the three intersection points be less than a specified test area, usually 50 square meters. If the area is greater than this specified test area, the azimuths are considered erroneous and the output consists of azimuth corrections. If the computed area is less than or equal to the test area, the "impact" is taken to be the average of the three intersection points. The range and deflection are computed in the same manner described in the case for two towers (Figure 3).

For four towers, the towers are grouped three to a set to form various combinations. That combination which forms the smallest triangular area will be used to determine the range and

deflection, provided its area is less than or equal to the specified test area. "Impact" is the average of the three intersections. Range and deflection are computed as before (Figure 4).

The geometry and trigonometry of how range and deflection are computed for two, three, or four tower readings are illustrated in Figure 5.

Computing altitude (height of burst) for an airburst round from the elevation measured from a tower is illustrated in Figure 6. Altitudes are computed for each tower and then averaged. Times of flight measured with stop clocks from each tower are also averaged.

The triangulation computer program written for the Aberdeen Proving Ground (APG) by Dennis Flaherty and related information are shown in Appendices A, B, C, and D. It should be noticed in his program that azimuths are measured clockwise from due south. Notice also that the cartesian coordinate system with origin at the gun has its x-axis inclined 35 degrees from due south and is right-handed with the positive z-axis going into the ground. The program can easily be modified for use at Yuma and Dugway Proving Grounds where azimuths are measured clockwise from due north and where the cartesian coordinate system with origin at the gun has its x-axis due north and its y-axis due east.

4. DISCUSSION

The accuracy of triangulation is very good if we can assume that at least three tower azimuth readings are good and if we can assume that the true impact is within the formed triangle. Making such assumptions and supposing that the formed triangle is a square right triangle of 50 square meters, the range and deflection errors cannot be larger than 7.46 meters.

For small ground impact firing tests, it is possible for a person to mark the crater location formed by the impacting round with a stake and to have all towers triangulate on the stake. If one does this, one should obtain near perfect accuracy for range and deflection values. However, this process is very laborious and time consuming, and is impractical to be used for large test firing plans. In such cases,

and for air burst occasions, burst sightings from towers are relied upon. When so, it is conceivable that all towers can triangulate perfectly but because of like systematic tower errors, be off the true mark.

Triangulation, which is based on burst sightings, does have its critics. Mr. Robert Lieske, a supervisor and colleague of mine, has argued that when four tower readings are used under such circumstances and all four readings are relatively good, triangulation does not use all the information it has access to. When using many towers, he has suggested an alternative technique based on a least squares method which minimizes angular error and which selectively uses all the information. Mr. Lieske believes that minimizing angular error is more efficient than minimizing the area of a triangle. Hopefully, this technique can be explained in a subsequent report.

5. CONCLUSION

In conclusion, it is hoped by the author that the objectives in writing this report and mentioned in the introduction have been achieved. The triangulation computer program is on the Vax 8600 and 780 computers in the Launch and Flight Division of BRL.

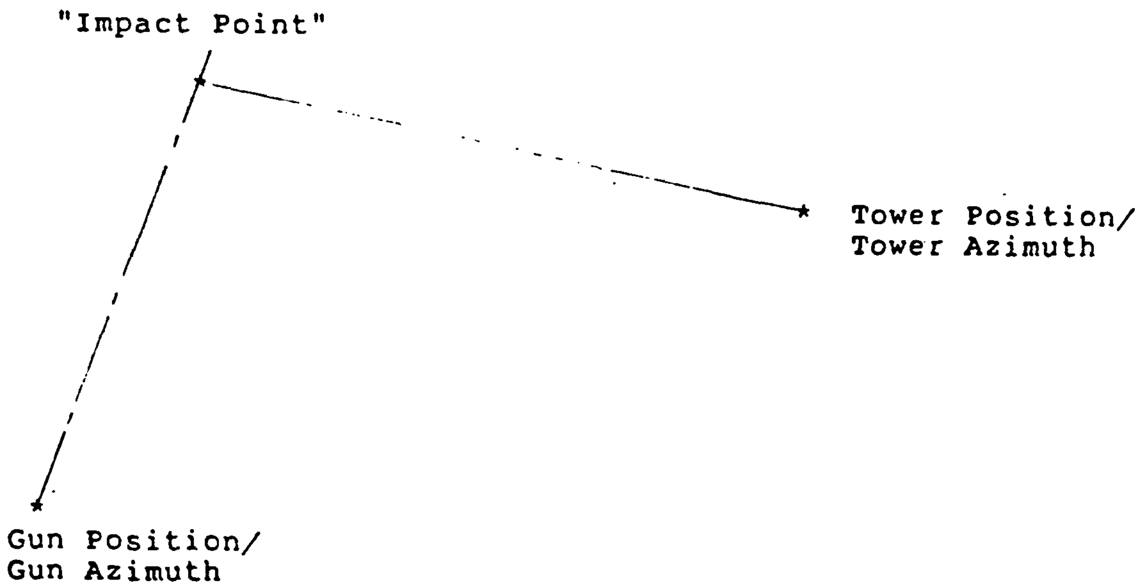
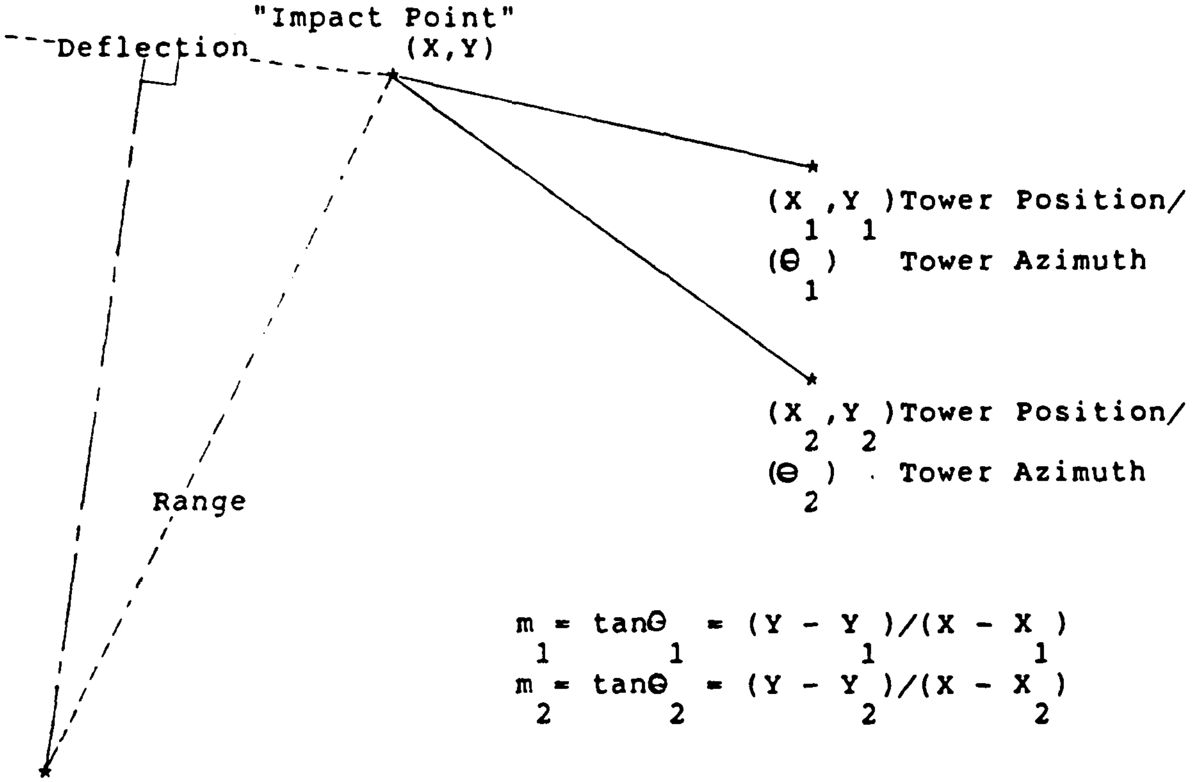


Figure 1. <u>One Tower Reading</u>.



$$m_1 = \tan\Theta_1 = (Y - Y_1)/(X - X_1)$$
$$m_2 = \tan\Theta_2 = (Y - Y_2)/(X - X_2)$$

gives two equations in two unknowns (X,Y) which can easily be solved for

Figure 2. Two Tower Readings.

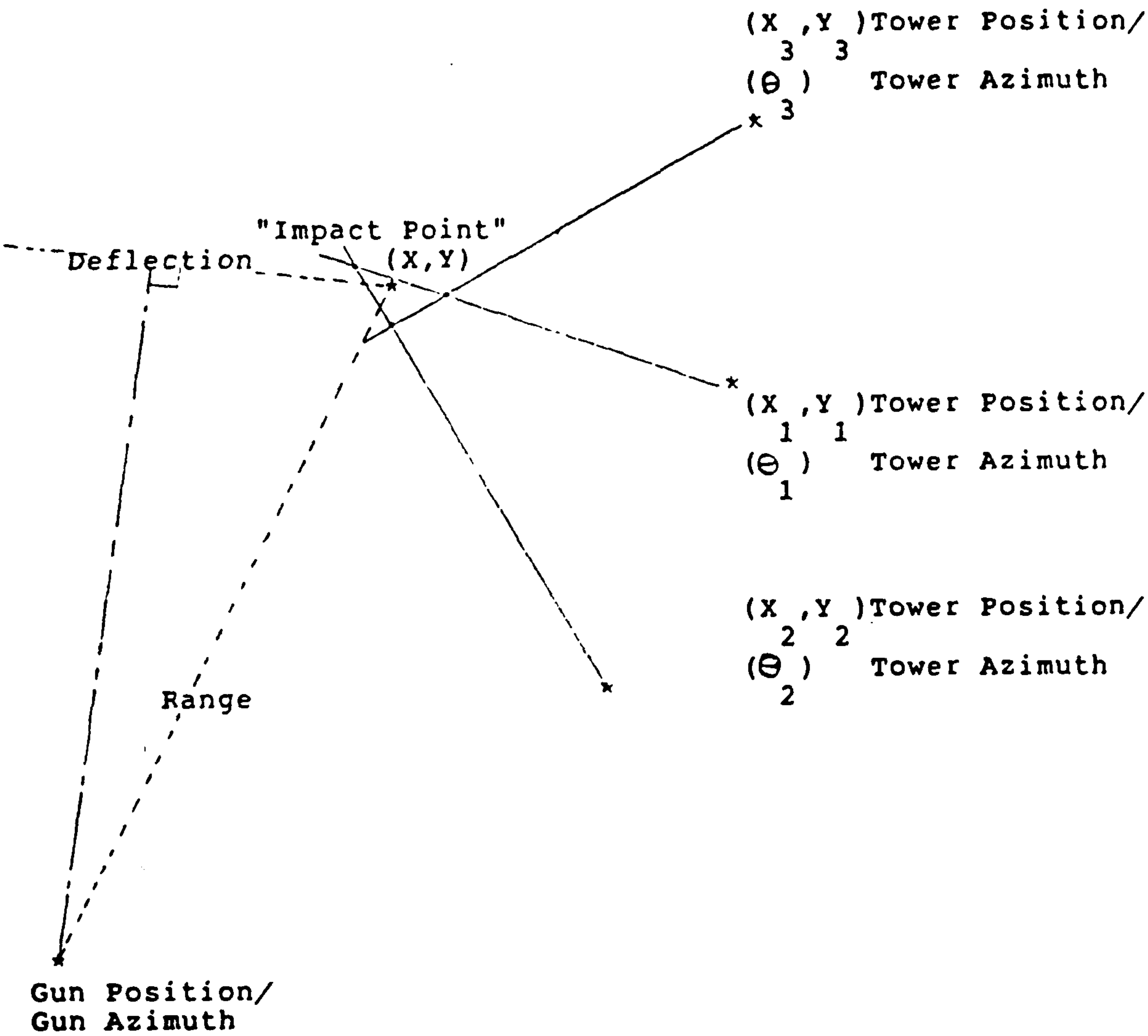


Figure 3. Three Tower Readings.

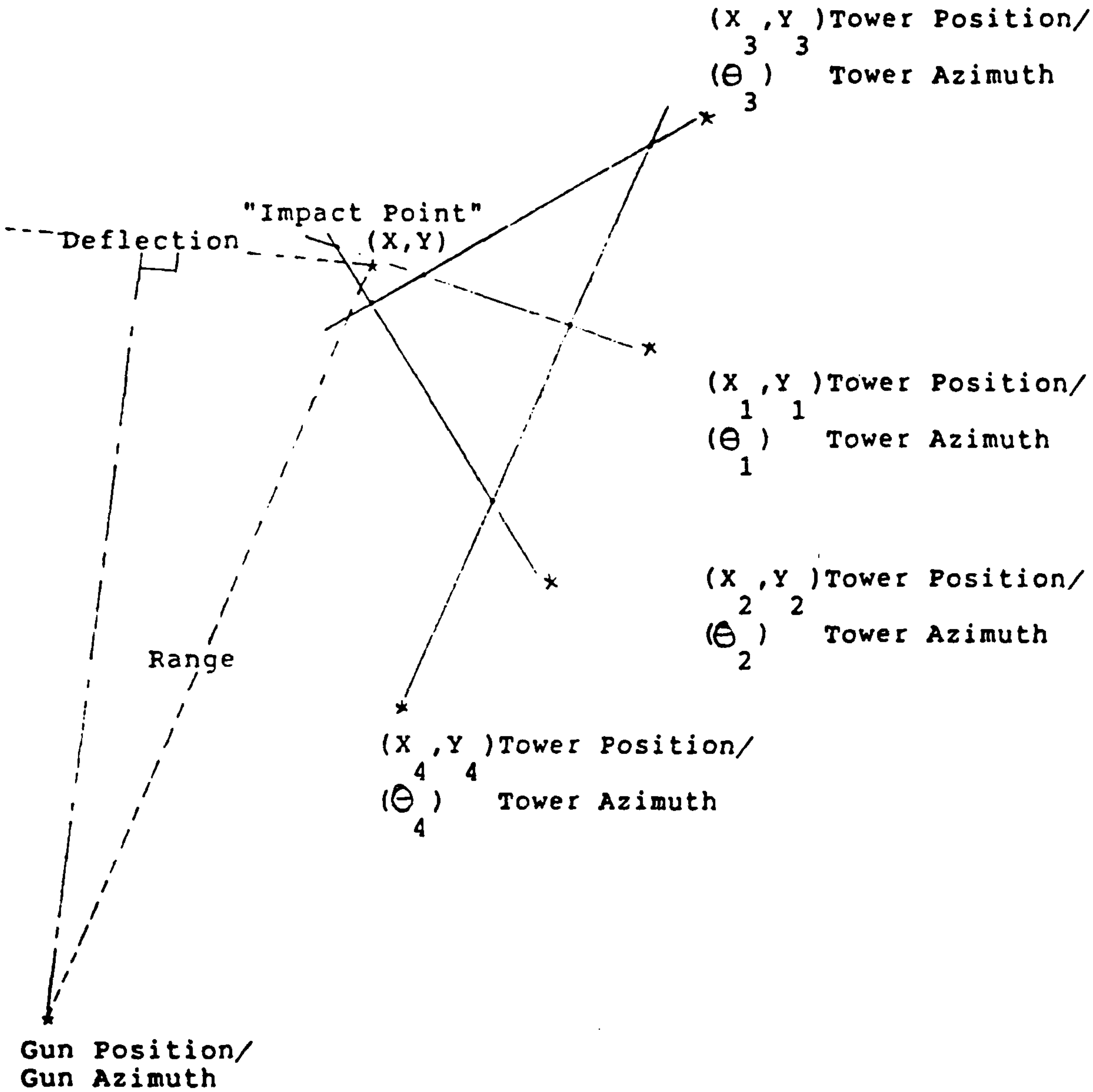


Figure 4. Four Tower Readings.

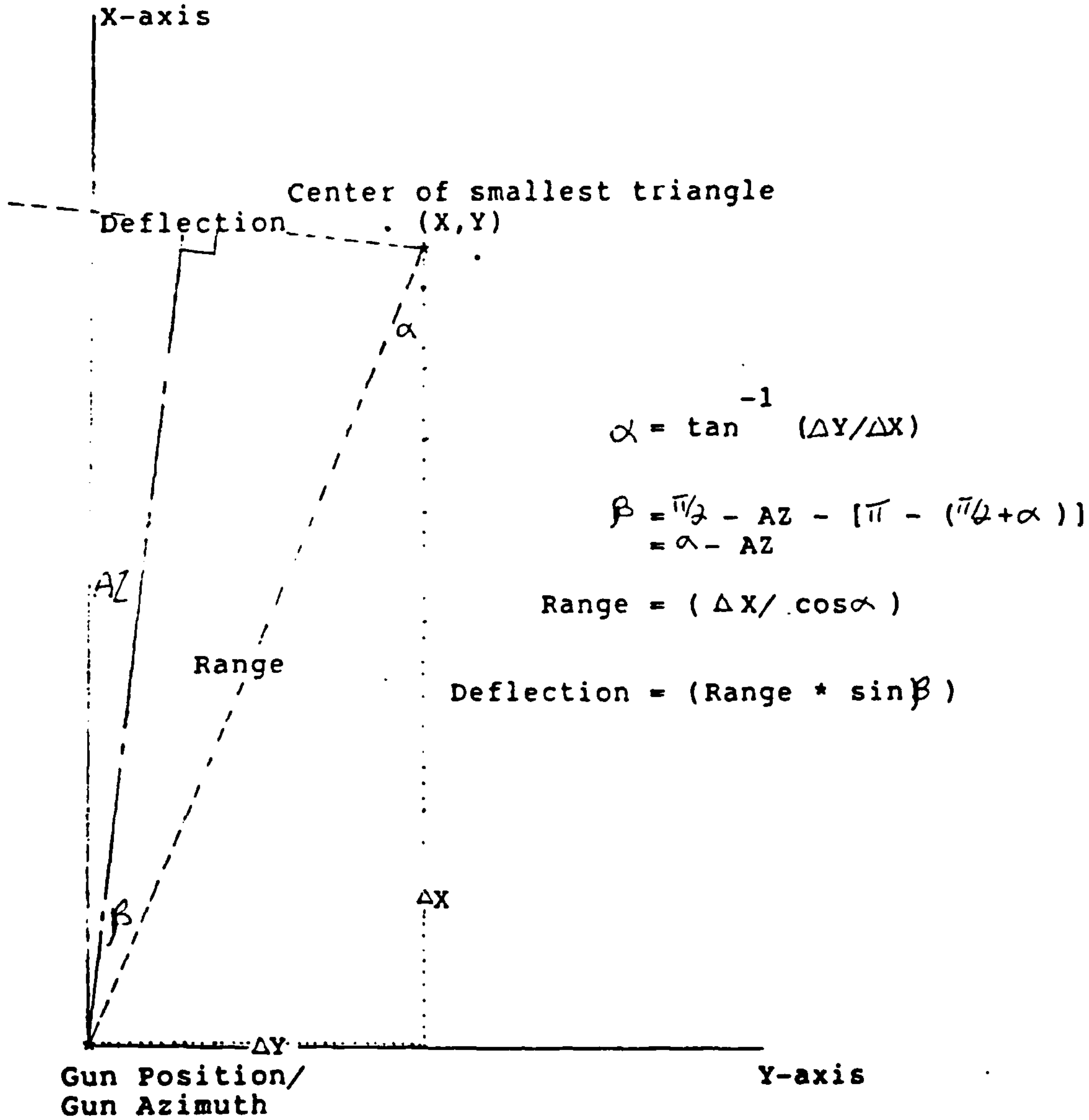


Figure 5. Illustration of How Range and Deflection are Computed.

$$HOB = HI + [R_1 * \tan(ELEV_1)]$$

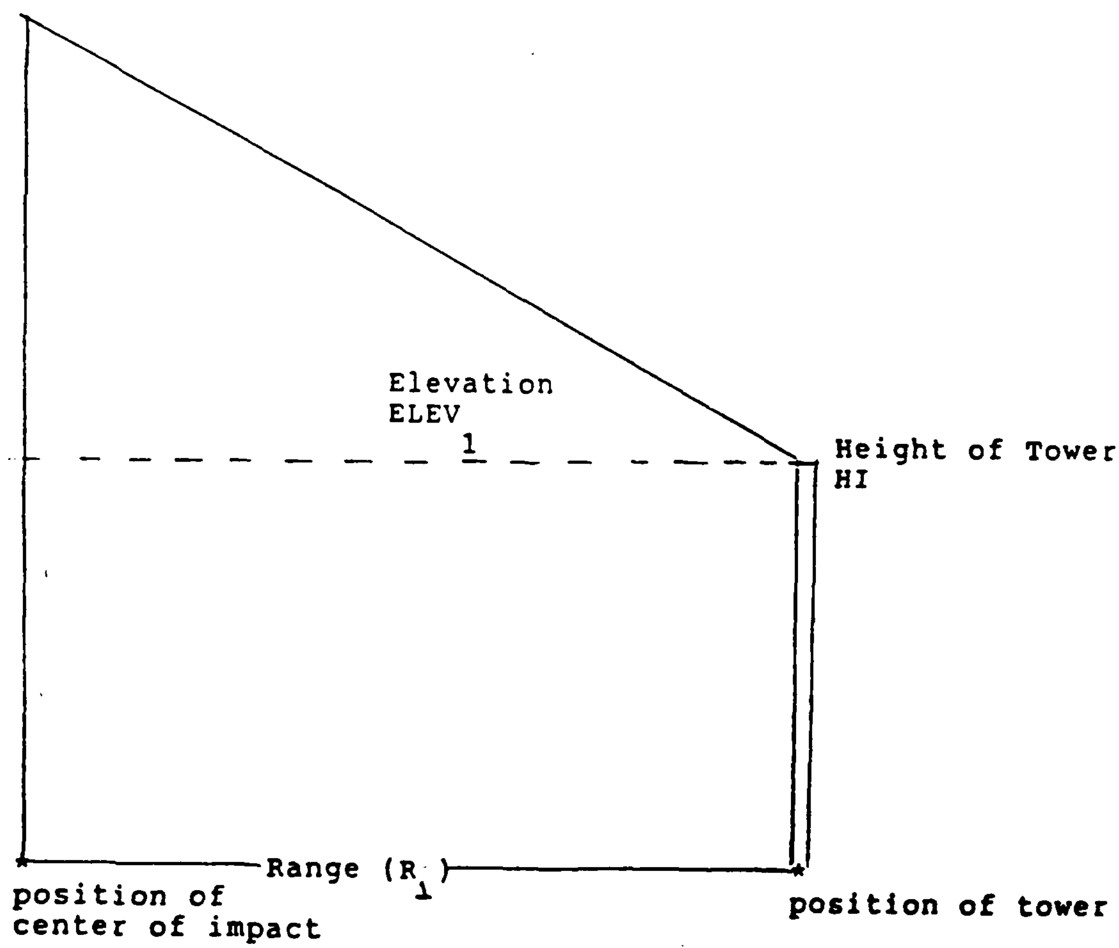


Figure 6. Illustra'ion of How Height of Burst (HOB) is Computed.

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APPENDIX A:
LISTING OF INPUT TO TRIANGULATION PROGRAM;
DEFINITIONS OF INPUT TO TRIANGULATION PROGRAM;
DESCRIPTION OF OUTPUT TO TRIANGULATION PROGRAM

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LISTING OF INPUT TO TRIANGULATION PROGRAM

All input is punched into a file, using the following format.

For IRX = 01 or 02

Items	Format
IRX (01 or 02)	I2
GUN	14A4
XLOC (location)	13A4
DATE	14A4
PRENG (Project Engineer)	11A4
ELEV (Elevation - ft.), ABOVE	F6.2, 1X, 6A4
KRD, N, NSTEP, A	3I4, F20.0
X_1 Y_1	2F11.3
. . N < 4	
X_n Y_n	
X_5, Y_5, AZD, AZM	4F11.3

For N of Towers:

AZD, AZM, ALX, BEX, ALPHA, TIME, SID	2F7.2, 2F7.2, A8, F6.2, A4

If blank data use -999 for both AZD and ALX
If blank data for time, leave TIME blank on input card

.
.
AZD_n
+999.

For IRX = 03 or 04

IRX	I2
*U, V, HI, HCOR	4F11.3

*For each tower

IRX
999999.
05 Termination

Note: Maximum number of tower readings 199.

Note: When using IRX of 03 be sure to use specified point coordinate for gun coordinates if no gun coordinates are given.

DEFINITIONS OF INPUT TO TRIANGULATION PROGRAM

IRX	An integer equal to 1,2,3, or 4 - it specifies the type of run. 1 - Compute range and deflection 2 - Computes impact coordinates in APG grid system 3 - Computes distance from specified point (e.g. tower or weapon) to impact point 4 - Computes altitude
GUN	56 character alphanumeric field weapon identification
XLOC	56 character alphanumeric field weapon location
DATE	56 character alphanumeric field date
PRENG	44 character alphanumeric field project engineer
ELEV	Height of weapon (feet)
ABOVE	24 character alphanumeric field - specifies reference level for weapon elevation
KRD	sequence number of first round
N	number of towers
NSTEP	Increment for round number
A	Limiting area (used with 3 or 4 towers)
X_i Y_i	Position coordinates of i-th tower (i 4) in APG grid system
X_5 Y_5	Position coordinates of weapon, APG system
AZD, AZM	Line of fire measured from south, in degrees and minutes
AZD, AZM	(second set) Tower readings measured south in degrees and minutes
ALX, BEX	Tower elevation readings of burst height, in degrees and minutes
ALPHA	8 character alphanumeric field used to label a tower reading
TIME	Observed time of flight from a given tower, in seconds
SID	4 character alphanumeric character S to be used to identify a spotter round as opposed to a numbered round
U, V	Position coordinates of tower (used for IRX = 03 or 04) in APG system (meters)
HI	Elevation correction, in meters (used for IRX=04)
HCOR*	Elevation correction, in minutes (used for IRX=04)

*As of 26 June 75, there will no longer be a requirement of HCOR for APG firings.

DESCRIPTION OF OUTPUT TO TRIANGULATION PROGRAM

Taking the various conditions in order, the output formats are as follows:

I. IRX = 1

Output is stored until the completion of the processing run. If any error rounds are encountered, the checking routine prints out the corrections as follows:

RANGE FIRING SUMMARY ERROR CORRECTIONS

Round No.	AREA (I6, D16.9)	The area has been calculated as larger than the standard value given on input
Tower X	Azimuth X (2I4, 1X, F7.3)	
Tower Y	Azimuth Y	
Tower Z	Azimuth Z	To correct such an error one of the tower readings is changed to the azimuth given or the standard area is increased to be greater than the calculated area.

The azimuths are given in integral degrees, and minutes to three decimal places.

If no errors are encountered during the processing run the normal type output process is reached. A page would resemble the following:

RANGE FIRING SUMMARY COPY 1 OF 3

GUN 175 MM GUN LOCATION X RANGE
DATE 28 MAY 1969 PROJECT ENGINEER MR. SMITH
ELEVATION OF TRUNNION 6.73 FT ABOVE MLW

AZIMUTH LINE OF FIRE

RDS 1 to 20 AZ 35D 3.72 M

Rd No.	Deflection mils	Deflection meters	Range meters	Ord of Det	Times of Flight 1	2	3	4	Mean
I6	F6.1	F6.1	F8.1	A8	F6.2	F6.2	F6.2	F6.2	F6.2

Three copies are printed for each run.

II. IRX = 2

The error checking procedure and output are the same as for IRX = 1. The standard output is as follows.

```
                    RANGE FIRING SUMMARY          COPY 1 of 3

GUN 175 MM                                  LOCATION  X - RANGE
DATE  28 MAY 1969                           PROJECT ENGINEER   MR. SMITH
ELEVATION OF TRUNNION  6.73 ft above MLW

                 AZIMUTH LINE OF FIRE

                Rds 1 to 20     AZ 350D  3.72 M

                GRID COORDINATES OF POINT OF IMPACT

ROUND             X        Y

 I6             F17.2    F17.2
```

Again three copies are provided.

III. IRX = 3

```
                    RANGE FIRING SUMMARY          COPY 1 of 3

ROUND     N* (RANGE,    TANGENT     BHT)      AV BHT       DIFF

  I6      N (1X,  F8.1, 1X, F9.5, 1X, F5.1)  F5.1         F5.1
```

N represents the number of towers or other reference taking readings
1 N 4

```
ROUND      AVBHT      DIFF      These are copies of the respective columns
 I6         F5.1      F5.1      above.  Only one copy of this set is provided.
                                There are three for the above.
```

APPENDIX B:
LISTING OF TRIANGULATION COMPUTER PROGRAM
WRITTEN FOR THE ABERDEEN PROVING GROUND, MARYLAND,
BY DENNIS FLAHERTY

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```
C     PROGRAM = 52.00
C     IMPACT LOCATION FROM TOWER OBSERVATIONS 1, 2, 3, OR 4 TOWERS
C     FORTRAN IV
C     APRIL 1966
C        PROGRAM REVISED MARCH 1971
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*4 GUN,XLOC,DATE,PRENG,ELEV,ABOVE
      INTEGER * 4 SID,S,SPOTZ
      COMMON KPOINT,KRDN,DEFLM,DEF,RN,ALP,BET,BHMAX,BHMIN,BHBAR,RNG,TANK
     1,BH,NNTUV
      DIMENSION X(5),Y(5),AZ(201,5),ISB(4),PT(12,2),ISC(3),CNT(2)
      DIMENSION KPOINT(201),KRDN(201),DEFLM(201),DEF(201),RN(201)
      DIMENSION GUN(14),XLOC(13),DATE(14),PRENG(11),ABOVE(6)
      DIMENSION TIME(4,200),ALPHA(4,200),DIV(200)
      DIMENSION ALP(200),BET(200),BBH(3)
      DIMENSION BHMAX(200),BHMIN(200),BHBAR(200)
      DIMENSION RNG(4,200),TANK(4,200),BH(4,200)
      DIMENSION NNTUV(200),IRND(5)
      DIMENSION ALX(5,200),BEX(5,200),SID(4,200),S(50)
      DATA SPOTZ/'S   '/
10    READ(5,1040)IRX
      GO TO (11,11,12,12,600),IRX
12    READ(5,1011)U,V,HI,HCOR
      IF(U .EQ. 999999.D0) GO TO 450
121   KNTUV=KNTUV+1
      IF(KNTUV .GT. 1) GO TO 122
      DO 1200 MN=1,200
1200  NNTUV(MN)=0
122   IF(IRX .EQ. 3) GO TO 17
123   ICNT=ICNT+1
      M=ICNT
      L=IRND(M)
      DO 15 K=1,L
      IF(ALX(M,K).EQ.-999.D0) GO TO 815
      NNTUV(K)=NNTUV(K)+1
      ALX(M,K)=(ALX(M,K)+(BEX(M,K)+HCOR)/60.D0)*.017453293
815   BET(K)=BEX(M,K)
      ALP(K)=ALX(M,K)
15    CONTINUE
17    GO TO (71,10),IERR
11    READ(5,3100)GUN
      II=1
      DO 1 IQZ=1,50
1     S(IQZ)=SPOTZ
      READ(5,3150)XLOC,DATE,PRENG,ELEV,ABOVE
      READ(5,1000) KRD,N,NSTEP,A
      KNTUV=0
      DO 13 J=1,200
      BHMAX(J)=0.D0
      BHMIN(J)=999999.D0
      BHBAR(J)=0.D0
13    DIV(J)=N
      IERR=1
      DO 20 I=1,N
20    READ(5,1010)X(I),Y(I)
      READ(5,1011)X(5),Y(5),AZD,AZM
      KDEG=AZD+.5
      DKMIN=AZM
      AZ(1,5)=((AZD+AZM/60.D0)-35.D0)*.017453293
      IRDG=0
```

```
      ICNT=0
      DO 70 J=1,N
      K=1
      DO 70 I=1,200
      GO TO (30,60),K
30    READ(5,1030)AZD,AZM,ALX(J,I),BEX(J,I),ALPHA(J,I),TIME(J,I),SID(J,I
     1)
      AZ(I,5)=AZ(1,5)
32    IF(AZD .EQ. -999.D0) GO TO 60
33    IF(AZD .NE. 999.D0) GO TO 50
34    IF (IRDG-I)35,40,40
35    IRDG=I
40    K=2
      IRND(J)=I-1
      GO TO 60
50    AZ(I,J)=((AZD+AZM/60.D0)-35.D0)*.017453293
      GO TO 65
60    AZ(I,J)=99999.D0
65    IF(TIME(J,I))70,66,70
66    DIV(I)=DIV(I)-1.
70    CONTINUE
      IRDG=IRDG-1
      LL=1
71    DO 280 I=1,IRDG
      IF(SID(1,I).EQ.S(II)) II=II+1
      IF(SID(1,I).EQ.S(II)) GO TO 772
      KRDNO=KRD+NSTEP*(LL-1)
      LL=LL+1
772   NHR=1
      J=1
      DO 90 K=1,N
      IF(AZ(I,K) .EQ. 99999.D0) GO TO 90
80    NHR=NHR+1
      ISB(J)=K
      J=J+1
90    CONTINUE
      GO TO (274,110,120,130,140),NHR
110   ISB(2)=5
120   LSV=1
      CALL POINT(AZ,I,ISB,1,2,X,Y,PT,LSV)
      CNT(1)=PT(1,1)
      CNT(2)=PT(1,2)
      GO TO 254
130   LST=4
      GO TO 150
140   LST=1
150   ARSV=1.D20
      DO 240 L=LST,4
      CALL ISCR(L,ISC)
      IF (NHR-4)160,160,200
160   DO 170 IBC=1,3
170   ISC(IBC)=ISB(IBC)
200   DO 210 J=1,2
      KST=J+1
      DO 210 K=KST,3
210   CALL POINT(AZ,I,ISC,J,K,X,Y,PT,L)
220   CALL AREA(PT,L,AR)
      IF (ARSV-AR)240,230,230
230   ARSV=AR
      LSV=L
```

```
240   CONTINUE
      IF (ARSV-A)250,250,300
250   CALL CNTR(PT,LSV,CNT)
254   GO TO (255,280),IERR
255   GO TO (260,270,400,400),IRX
260   CALL RANGE(X(5),Y(5),AZ(1,5),CNT,RN(I),DEFL,DEFLML)
      KPOINT(I)=1
      KRDN(I)=KRDNO
      DEFLM(I)=DEFLML
      DEF(I)=DEFL
      GO TO 280
270   KPOINT(I)=2
      KRDN(I)=KRDNO
      DEFLM(I)=CNT(1)
      DEF(I)=CNT(2)
      GO TO 280
274   GO TO (275,280),IERR
275   KPOINT(I)=3
      IF(IRX .GT. 2) GO TO 280
      KRDN(I)=KRDNO
280   CONTINUE
      GO TO (285,10),IERR
285   GO TO (500,500,10,10,600),IRX
300   GO TO (310,320),IERR
310   IERR=2
      WRITE(6,4000)
320   IF(NHR-4)340,340,330
330   CALL ISCR(LSV,ISC)
      M=3*LSV+1
      GO TO 350
340   M=13
350   IF(SID(1,I).EQ.S(II)) GO TO 352
      WRITE(6,2031)KRDNO,ARSV
      GO TO 353
352   IQ=II-1
      WRITE(6,2033)IQ,ARSV
353   DO 390 J=1,3
      JISC=ISC(J)
      ANUM=PT(M-J,2)-Y(JISC)
      ADEN=PT(M-J,1)-X(JISC)
      CALL ATNSR(ANUM,ADEN,CORR,1)
      CORR=CORR/.017453293+35.D0
360   IF(CORR .LT. 360.D0) GO TO 380
370   CORR=CORR-360.D0
380   ICORR=CORR
      CORR=(CORR-DFLOAT(ICORR))*60.D0
      CORRA=CORR/60.
      CORRH=FLOAT(ICORR)+CORRA
390   WRITE(6,2032)ISC(J),ICORR,CORR,CORRH
      GO TO 280
400   CALL RANGE(U,V,AZ(1,5),CNT,RNG(KNTUV,I),DEFL,DEFLML)
      IF(ALP(I) .EQ. -999.D0) RNG(KNTUV,I)=0.D0
      IF(IRX .EQ. 3) GO TO 425
      KONTRL=1
      IF(ALP(I) .NE. -999.D0) GO TO 420
401   TANK(KNTUV,I)=0.
      BH(KNTUV,I)=0.
      GO TO 280
420   TANK(KNTUV,I)=DTAN(ALP(I))
      BH(KNTUV,I)=RNG(KNTUV,I)*TANK(KNTUV,I)+HI
```

```
      BHMAX(I)=DMAX1(BHMAX(I),BH(KNTUV,I))
      BHMIN(I)=DMIN1(BHMIN(I),BH(KNTUV,I))
      BHBAR(I)=BHBAR(I)+BH(KNTUV,I)
      GO TO 280
425   KONTRL=2
      GO TO 280
450   IF(IERR .EQ. 2) GO TO 10
      DO 470 KOPY=1,3
      WRITE(6,3200)KOPY
      GO TO (460,451),KONTRL
451   DO 453 J=1,KNTUV
      WRITE(6,1014)J
      DO 452 I=1,IRDG
      IF(KPOINT(I).EQ.3) GO TO 4530
      IF(SID(J,I).EQ.S(II)) GO TO 4522
      WRITE(6,1016)KRDN(I),RNG(J,I)
      GO TO 452
4530  IF(SID(J,I).EQ.S(II)) WRITE(6,1216)
      IF(SID(J,I).NE.S(II)) WRITE(6,1316)KRDN(I)
1316  FORMAT(1H ,I6)
1216  FORMAT(1H ,'  SPOT')
      GO TO 452
4522  WRITE(6,1116)RNG(J,I)
452   CONTINUE
453   CONTINUE
      GO TO 470
460   DO 462 I=1,IRDG
      IF(KOPY .GT. 1) GO TO 461
      IF(NNTUV(I) .EQ. 0) NNTUV(I)=1
      BHMAX(I)=BHMAX(I)-BHMIN(I)
      BHBAR(I)=BHBAR(I)/DFLOAT(NNTUV(I))
461   GO TO (4611,4612,4613,4614),KNTUV
4611  IF(I .EQ. 1) WRITE(6,1021)
      IF(SID(1,I).EQ.S(II)) GO TO 4711
      WRITE(6,1061) KRDN(I),((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),
     1BHBAR(I),BHMAX(I)
      GO TO 462
4711  WRITE(6,1161)((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),BHBAR(I),
     1BHMAX(I)
      GO TO 462
4612  IF(I .EQ. 1) WRITE(6,1022)
      IF(SID(1,I).EQ.S(II)) GO TO 4712
      WRITE(6,1062) KRDN(I),((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),
     1BHBAR(I),BHMAX(I)
      GO TO 462
4712  WRITE(6,1162)((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),BHBAR(I),
     1BHMAX(I)
      GO TO 462
4613  IF(I .EQ. 1) WRITE(6,1023)
      IF(SID(1,I).EQ.S(II)) GO TO 4713
      WRITE(6,1063) KRDN(I),((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),
     1BHBAR(I),BHMAX(I)
      GO TO 462
4713  WRITE(6,1163)((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),BHBAR(I),
     1BHMAX(I)
      GO TO 462
4614  IF(I .EQ. 1) WRITE(6,1024)
      IF(SID(1,I).EQ.S(II)) GO TO 4714
      WRITE(6,1064) KRDN(I),((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),
     1BHBAR(I),BHMAX(I)
```

```
      GO TO 462
4714  WRITE(6,1164)((RNG(J,I),TANK(J,I),BH(J,I)),J=1,KNTUV),BHBAR(I),
     1BHMAX(I)
462   CONTINUE
      WRITE(6,1017)
      DO 469 J=1,IRDG
      IF(SID(1,J).EQ.S(II)) GO TO 468
465   WRITE(6,1019)KRDN(J),BHBAR(J),BHMAX(J)
      GO TO 469
468   WRITE(6,1119)BHBAR(J),BHMAX(J)
469   CONTINUE
470   CONTINUE
      GO TO 10
500   LAST=KRD+NSTEP*(IRDG-1)
      DO 560 KOPY=1,3
      WRITE(6,3200)KOPY
      WRITE(6,3300)GUN,XLOC,DATE,PRENG,ELEV,ABOVE
      WRITE(6,3400)KRD,LAST,KDEG,DKMIN
      IF(IRX-2)503,501,503
501   WRITE(6,3700)
      GO TO 504
503   WRITE(6,3500)
      WRITE(6,3600)
504   DO 560 M=1,IRDG
      IBRNCH=KPOINT(M)
      GO TO (510,520,530,510,510),IBRNCH
510   PMEAN=0.D0
      DO 515 K=1,N
      IF(DIV(M))515,514,515
514   DIV(M)=1.
515   PMEAN=PMEAN+TIME(K,M)/DIV(M)
      KK=0
      DO 5999 MM=1,N
      IF(AZ(M,MM).EQ.99999.D0) KK=KK+1
5999  CONTINUE
      GO TO (5151,5152,5153,5154),N
5151  IF(SID(1,M).EQ.S(II)) GO TO 5551
      WRITE(6,2001)KRDN(M),RN(M),ALPHA(1,M),TIME(1,M),PMEAN
      GO TO 560
5551  WRITE(6,2101)RN(M),ALPHA(1,M),TIME(1,M),PMEAN
      GO TO 560
5152  IF(KK.EQ.1) GO TO 5252
      IF(SID(1,M).EQ.S(II)) GO TO 5352
      WRITE(6,2002)KRDN(M),DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M)
     1,TIME(2,M),PMEAN
      GO TO 560
5352  WRITE(6,2102)DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),
     1PMEAN
      GO TO 560
5252  IF(SID(1,M).EQ.S(II)) GO TO 5452
      WRITE(6,2012)KRDN(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),PMEAN
      GO TO 560
5452  WRITE(6,2112)RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),PMEAN
      GO TO 560
5153  IF(KK.EQ.2) GO TO 5253
      IF(SID(1,M).EQ.S(II)) GO TO 5353
      WRITE(6,2003)KRDN(M),DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M)
     1,TIME(2,M),TIME(3,M),PMEAN
      GO TO 560
5353  WRITE(6,2103)DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),
     1TIME(3,M),PMEAN
```

```
      GO TO 560
5253  IF(SID(1,M).EQ.S(II)) GO TO 5453
      WRITE(6,2013)KRDN(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),TIME(3,M
     1),PMEAN
      GO TO 560
5453  WRITE(6,2113)RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),TIME(3,M),PMEAN
      GO TO 560
5154  IF(KK.EQ.3) GO TO 5254
      IF(SID(1,M).EQ.S(II)) GO TO 5354
      WRITE(6,2000)KRDN(M),DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M)
     1,TIME(2,M),TIME(3,M),TIME(4,M),PMEAN
      GO TO 560
5354  WRITE(6,2100)DEFLM(M),DEF(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),
     1TIME(3,M),TIME(4,M),PMEAN
      GO TO 560
5254  IF(SID(1,M).EQ.S(II)) GO TO 5454
      WRITE(6,2014)KRDN(M),RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),TIME(3,M
     1),TIME(4,M),PMEAN
      GO TO 560
5454  WRITE(6,2114)RN(M),ALPHA(1,M),TIME(1,M),TIME(2,M),TIME(3,M),TIME(4
     1,M),PMEAN
      GO TO 560
520   IF(SID(1,M).EQ.S(II)) GO TO 5201
      WRITE(6,2010)KRDN(M),DEFLM(M),DEF(M)
      GO TO 560
5201  WRITE(6,2110)DEFLM(M),DEF(M)
      GO TO 560
530   IF(SID(1,M).EQ.S(II)) GO TO 5301
      WRITE(6,2020)KRDN(M)
      GO TO 560
5301  WRITE(6,2120)
560   CONTINUE
      GO TO 10
600   CALL EXIT
2110  FORMAT(1H0,'  SPOT',1X,F17.2,1X,F13.2/)
2114  FORMAT(1H ,'  SPOT',T14,'-------',T29,'-------',T42,F8.1,4X,A8,3X,4(
     1F6.2,4X),F6.2)
2014  FORMAT(1H ,I6,T14,'-------',T29,'-------',T42,F8.1,4X,A8,3X,4(F6.2,4
     1X),F6.2)
2102  FORMAT(1H ,'  SPOT',T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,2(F6.2,4X)
     1,20X,F6.2)
2002  FORMAT(1H ,I6,T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,2(F6.2,4X),20X,F
     16.2)
2100  FORMAT(1H ,'  SPOT',T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,5(F6.2,4X)
     1)
2000  FORMAT(1H ,I6,T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,5(F6.2,4X))
2010  FORMAT(1H0,I6,1X,F17.2,1X,F13.2/)
1000  FORMAT(3I4,F20.0)
1010  FORMAT(2F11.3)
1011  FORMAT(4F11.3)
1015  FORMAT(F4.0,1X,F3.0)
1016  FORMAT(1H ,I6,F17.1,1X,F9.5,1X,F5.1)
1116  FORMAT(1H ,'  SPOT',F17.1,1X,F9.5,1X,F5.1)
1017  FORMAT(1H1,1X,'ROUND',9X,'AVBHT',6X,'DIFF'/,' ',15X,'METERS',/)
1119  FORMAT(1H ,'  SPOT',8X,F6.1,6X,F5.1)
1019  FORMAT(1H ,I6,8X,F6.1,6X,F5.1)
1014  FORMAT(1H ,'TOWER ',I1/)
1021  FORMAT(1H0,T24,'1'/
     11H ,' ROUND',1('    RANGE    TANGENT     BHT'),'  AVBHT  DIFF')
```

```
1022  FORMAT(1H0,T24,'1',T49,'2'/
     21H ,' ROUND',2('     RANGE    TANGENT     BHT'),'   AVBHT   DIFF')
1023  FORMAT(1H0,T24,'1',T49,'2',T74,'3'/
     31H ,' ROUND',3('     RANGE    TANGENT     BHT'),'   AVBHT   DIFF')
1024  FORMAT(1H0,T24,'1',T49,'2',T74,'3',T99,'4'/
     41H ,' ROUND',4('     RANGE    TANGENT     BHT'),'   AVBHT   DIFF')
1030  FORMAT(2F7.2,2F7.2,A8,F6.2,A4)
1040  FORMAT(I2)
1050  FORMAT(1H I6,D16.9)
1061  FORMAT(1H ,I6,1(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1161  FORMAT(1H ,'  SPOT',1(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1062  FORMAT(1H ,I6,2(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1162  FORMAT(1H ,'  SPOT',2(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1063  FORMAT(1H ,I6,3(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1163  FORMAT(1H ,'  SPOT',3(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
1064  FORMAT(1H ,I6,4(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
2001  FORMAT(1H ,I6,T14,'------',T29,'------',T42,F8.1,4X,A8,3X,F6.2,34X
     1,F6.2)
1164  FORMAT(1H ,'  SPOT',4(1X,F8.1,1X,F9.5,1X,F6.1),1X,F6.1,1X,F5.1)
2101  FORMAT(1H ,'  SPOT',T14,'------',T29,'------',T42,F8.1,4X,A8,3X,F6
     1.1,34X,F6.2)
2012  FORMAT(1H ,I6,T14,'------',T29,'------',T42,F8.1,4X,A8,3X,2(F6.2,4
     1X),20X,F6.2)
2112  FORMAT(1H ,'  SPOT',T14,'------',T29,'------',T42,F8.1,4X,A8,3X,2(
     1F6.2,4X),20X,F6.2)
2013  FORMAT(1H ,I6,T14,'------',T29,'------',T42,F8.1,4X,A8,3X,3(F6.2,4
     1X),10X,F6.2)
2113  FORMAT(1H ,'  SPOT',T14,'------',T29,'------',T42,F8.1,4X,A8,3X,3(
     1F6.2,4X),10X,F6.2)
2103  FORMAT(1H ,'  SPOT',T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,3(F6.2,4X)
     1,10X,F6.2)
2003  FORMAT(1H ,I6,T14,F6.1,T29,F6.1,T42,F8.1,4X,A8,3X,3(F6.2,4X),10X,F
     16.2)
2120  FORMAT(1H0,'  SPOT')
2020  FORMAT(1H0,I6/)
2031  FORMAT(1H0,I6,1X,D16.9)
 2032 FORMAT(1H ,2I4,1X,F7.3,1X,F8.3)
2033  FORMAT(1H0,' SPOT',I2,1X,D16.9)
3100  FORMAT(14A4)
3150  FORMAT(13A4/14A4/11A4/F6.2,1X,6A4)
3200  FORMAT(1H1,50X,'RANGE FIRING SUMMARY',T110,'COPY ',I1,'OF 3')
3300  FORMAT(1H0,'GUN ',14A4,' LOCATION ',13A4/1H ,'DATE ',14A4,'PROJECT
     1 ENGINEER ',11A4/1H ,'ELEVATION OF TRUNNIONS ',F6.2,' FT. ABOVE ',
     26A4)
3400  FORMAT(1H0,T51,'AZIMUTH LINE OF FIRE'/1H ,T44,'RDS. ',I6,' TO ',I6
     1,' AZ. ',I3,' D ',F5.2,' M ')
3500  FORMAT(1H0,'RD.NO.',T18,'DEFLECTIONS',T43,'RANGE',T53,'ORD OF DET'
     1,T85,'TIMES OF FLIGHT')
3600  FORMAT(1H ,T15,'MILS',T29,'METERS',T43,'METERS',T68,'1',T78,'2',
     1T88,'3',T98,'4',T106,'MEAN'/)
3700  FORMAT(1H0,T43,'GRID COORDINATES OF POINT OF IMPACT'/1H0,
     1' ROUND',11X,'    X    ',8X,'    Y    '/)
4000  FORMAT(1H1,'RANGE FIRING SUMMARY ERROR CORRECTIONS')
      END
```

```
      SUBROUTINE ISCR(L,I)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION I(3)
      K=1
      DO 20 J=1,4
      IF (J-L)10,20,10
10    I(K)=J
      K=K+1
20    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE POINT(AZ,I,ISC,J,K,X,Y,PT,L)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION AZ(201,5),ISC(3),X(5),Y(5),PT(12,2)
      M=3*L+J+K-5
      JISC=ISC(J)
      KISC=ISC(K)
      A=DTAN(AZ(I,JISC))
      B=DTAN(AZ(I,KISC))
      PT(M,1)=(X(JISC)*A-Y(JISC) +Y(KISC)-X(KISC)*B)/(A-B)
      PT(M,2)=(PT(M,1)-X(KISC))*B+Y(KISC)
      RETURN
      END
```

```
      SUBROUTINE AREA(P,L,A)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION P(12,2)
      I=3*L-2
      J=I+1
      K=I+2
      A=DABS(.5D0*((P(I,2)-P(J,2))*P(K,1)+(P(J,2)-P(K,2))*P(I,1)+
     1(P(K,2)-P(I,2))*P(J,1)))
      RETURN
      END
```

```
      SUBROUTINE CNTR(P,L,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION P(12,2),C(2)
      M=3*L-2
      DO 10 I=1,2
   10 C(I)=(P(M,I)+P(M+1,I)+P(M+2,I))/3.D0
      RETURN
      END
```

```
      SUBROUTINE RANGE(X,Y,AZ,CNT,RNG,DEFL,DEFLM)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION CNT(2)
      RNG=CNT(1)-X
      DEFL=CNT(2)-Y
      CALL ATNSR(DEFL,RNG,BETA,1)
      DEFLM=BETA-AZ
10    IF (DEFLM+3.14159265)30,30,20
20    IF (DEFLM-3.14159265)50,40,40
30    DEFLM=DEFLM+6.28318531
      GO TO 10
40    DEFLM=DEFLM-6.28318531
      GO TO 10
50    RNG=RNG/DCOS(BETA)
      DEFL=RNG*DSIN(DEFLM)
      DEFLM=1018.59164*DEFLM
      RETURN
      END
```

```
      SUBROUTINE ATNSR(A,B,C,L)
      IMPLICIT REAL*8(A-H,O-Z)
      P=3.14159265
      C=DATAN(A/B)
      IF (A)10,40,40
   10 IF (B)20,30,30
   20 GO TO (21,22),L
   21 C=P+C
      GO TO 50
   22 C=C-2.D0*P
      GO TO 50
   30 GO TO (31,50),L
   31 C=2.D0*P+C
      GO TO 50
   40 IF (B)20,50,50
   50 RETURN
      END
```

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APPENDIX C:
SAMPLE INPUT TO TRIANGULATION COMPUTER PROGRAM

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```
01
105MM
BALL PG.
22 MAY 85
SCHNELL
13.89   MLW
  11     4     1  50.
3657.607    12801.626
3868.530    13870.487
3754.335    13094.383
2883.79     11998.31
3812.273    12475.803   41.          26.
34.      22.       18.          51.   HOAB       15.67
34.      23.       17.          45.   ILLUM      16.11
34.      25.       18.          46.   HOAB       15.77
34.      18.       17.          41.   ILLUM      15.94
34.      11.       5.           35.   HOAB       12.28
34.      17.       5.           09.   GREN       12.02
34.      05.       5.           35.   GREN       11.46
34.      17.       5.           08.   GREN       11.72
+999.
11.      08.       19.          07.              16.03
9.       54.       18.          01.              16.39
11.      13.       19.          05.              15.80
9.       42.       17.          42.
10.      52.       6.           09.              11.55
11.      19.       6.           37.              11.63
10.      36.       6.           01.              11.69
11.      03.       5.           32.              11.99
+999.
26.      57.       20.          04.
27.      28.       18.          50.
27.      52.       19.          45.
27.      24.       18.          40.
27.      42.       6.           45.
27.      57.       5.           55.
27.      32.       6.           35.
27.      45.       5.           50.
+999.
47.      37.       14.          48.              15.70
47.      55.       13.          38.              17.40
47.      35.       14.          56.              15.73
48.      03.       13.          41.              17.90
47.      26.       4.           35.              11.52
47.      24.       4.           19.              12.07
47.      33.       4.           39.              11.40
47.      35.       4.           17.              11.76
+999.
04
3657.607    12801.626   32.13
04
3868.530    13870.487   13.3
04
3754.335    13094.383    4.77
04
2883.79     11998.31    12.13
04
999999.
05
```

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APPENDIX D:
SAMPLE OUTPUT FROM TRIANGULATION COMPUTER PROGRAM

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RANGE FIRING SUMMARY

COPY 1OF 3

GUN 105MM
DATE 22 MAY 85
ELEVATION OF TRUNNIONS 13.89 FT. ABOVE MLW

LOCATION BALL PG.
PROJECT ENGINEER SCHNELL

AZIMUTH LINE OF FIRE
RDS. 11 TO 18 AZ. 41 U 26.00 M

RD.NO.	DEFLECTIONS MILS	DEFLECTIONS METERS	RANGE METERS	ORD OF DET	TIMES OF FLIGHT 1	TIMES OF FLIGHT 2	TIMES OF FLIGHT 3	TIMES OF FLIGHT 4	MEAN
11	4.3	10.9	2551.5	HCAB	15.67	16.03	0.00	15.70	15.80
12	7.7	18.3	2433.0	ILLUM	16.11	16.39	0.00	17.40	16.63
13	4.4	11.1	2562.7	HUAB	15.77	15.80	0.00	15.73	15.77
14	9.4	22.3	2407.5	ILLUM	15.94	0.00	0.00	17.90	16.92
15	1.0	2.6	2543.3	HCAB	12.28	11.55	0.00	11.52	11.78
16	0.8	1.9	2587.1	GREN	12.02	11.63	0.00	12.07	11.91
17	0.2	0.5	2520.9	GREN	11.46	11.69	0.00	11.40	11.52
18	3.5	8.6	2530.4	GREN	11.72	11.99	0.00	11.76	11.82

RANGE FIRING SUMMARY

COPY 2OF 3

GLA 105MM
DATE 22 MAY 85
ELEVATION OF TRUNNIONS 13.89 FT. ABOVE PLN

LOCATION BALL PG.
PROJECT ENGINEER SCHNELL

AZIMUTH LINE OF FIRE
RDS. 11 TO 18 AZ. 41 D 26.00 M

RD.NO.	DEFLECTIONS MILS	DEFLECTIONS METERS	RANGE METERS	ORD OF DET	TIMES OF FLIGHT 1	2	3	4	MEAN
11	4.3	10.9	2551.5	HCAB	15.67	16.03	0.00	15.70	15.80
12	7.7	18.3	2433.0	ILLUM	16.11	16.39	0.00	17.40	16.63
13	4.4	11.1	2582.7	HDAB	15.77	15.80	0.00	15.73	15.77
14	9.4	22.3	2407.5	ILLUM	15.94	0.00	0.00	17.90	16.92
15	1.0	2.6	2542.3	HCAB	12.28	11.55	0.00	11.52	11.78
16	0.8	1.9	2587.1	GREN	12.02	11.63	0.00	12.07	11.91
17	0.2	0.5	2520.9	GREN	11.46	11.69	0.00	11.40	11.52
18	3.5	8.6	2530.4	GREN	11.72	11.99	0.00	11.76	11.82

COPY 3OF 3

RANGE FIRING SUMMARY

GLA 105MM
DATE 22 MAY 85
ELEVATION OF TRUNNIONS 13.89 FT. ABOVE MLW

LOCATION BALL PG.
PROJECT ENGINEER SCHNELL

AZIMUTH LINE OF FIRE
RDS. 11 TO 18 AZ. 41 D 26.00 M

RD.NO.	DEFLECTIONS MILS	METERS	RANGE METERS	ORD OF DET	TIMES OF FLIGHT 1	2	3	4	MEAN
11	4.3	10.5	2551.5	HCAB	15.67	16.03	0.00	15.70	15.80
12	7.7	18.3	2433.0	ILLUM	16.11	16.39	0.00	17.40	16.63
13	4.4	11.1	2562.7	HCAB	15.77	15.80	C.00	15.73	15.77
14	9.4	22.3	2407.5	ILLUM	15.94	0.00	0.00	17.90	16.92
15	1.0	2.6	2543.3	HCAB	12.28	11.55	0.00	11.52	11.78
16	0.8	1.9	2587.1	GREN	12.02	11.63	0.00	12.07	11.91
17	0.2	0.5	2520.9	GREN	11.46	11.69	0.00	11.40	11.52
18	3.5	8.6	2530.4	GREN	11.72	11.99	0.00	11.76	11.82

RANGE FIRING SUMMARY

COPY 1OF 3

	1			2			3			4				
RCLAD	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	AVBHT	DIFF
11	2689.1	0.34140	950.2	2710.3	0.34661	952.7	2612.1	0.36529	958.9	3548.2	0.26421	949.6	952.9	9.3
12	2570.4	0.32010	854.9	2604.8	0.32524	860.5	2495.1	0.34108	855.8	3431.2	0.24254	844.3	853.9	16.1
13	2700.1	0.33978	949.6	2719.9	0.34596	954.3	2622.9	0.35904	946.5	3559.4	0.26670	961.4	952.9	14.9
14	2544.6	0.31882	843.4	2581.0	0.31914	837.0	2469.4	0.33783	839.0	3406.3	0.24347	841.4	840.2	6.4
15	2681.9	0.09776	294.3	2707.4	0.10775	305.0	2606.0	0.11836	313.2	3539.1	0.08017	295.8	302.1	18.9
16	2725.4	0.09013	277.8	2745.6	0.11600	331.8	2648.7	0.10363	279.3	3582.6	0.07548	282.6	292.8	54.0
17	2660.0	0.09776	292.2	2689.3	0.10540	296.7	2584.8	0.11541	303.1	3516.7	0.08134	298.2	297.5	10.9
18	2668.4	0.08983	271.8	2693.3	0.09688	274.2	2592.1	0.10216	269.6	3526.9	0.07490	276.3	273.0	6.7

RCUNC	AVHFT METERS	CIFF
11	952.9	9.3
12	853.9	16.1
13	952.9	14.9
14	84C.2	6.4
15	302.1	18.9
16	292.8	54.0
17	257.5	10.9
18	273.0	6.7

RANGE FIRING SUMMARY

COPY 2OF 3

		1			2			3			4			
ROUND	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	AVBHT	DIFF
11	2689.1	0.34140	950.2	2710.3	0.34661	952.7	2612.1	0.36529	958.9	3548.2	0.26421	949.6	952.9	9.3
12	2570.4	0.32010	854.9	2604.8	0.32524	860.5	2495.1	0.34108	855.8	3431.2	0.24254	844.3	853.9	16.1
13	2700.1	0.33978	949.6	2719.9	0.34596	954.3	2622.9	0.35904	946.5	3559.4	0.26670	961.4	952.9	14.9
14	2544.6	0.31882	843.4	2581.0	0.31914	837.0	2464.4	0.33783	839.0	3406.3	0.24347	841.4	840.2	6.4
15	2681.9	0.09776	294.3	2707.4	0.10775	305.0	2606.0	0.11836	313.2	3539.1	0.08017	295.8	302.1	18.9
16	2725.4	0.09013	277.8	2745.6	0.11600	331.8	2648.7	0.10363	279.3	3582.6	0.07548	282.6	292.8	54.0
17	2660.0	0.09776	292.2	2689.3	0.10540	296.7	2584.8	0.11541	303.1	3516.7	0.08134	298.2	297.5	10.9
18	2668.4	0.08983	271.8	2693.3	0.09688	274.2	2592.1	0.10216	269.6	3526.9	0.07490	276.3	273.0	6.7

ROUND	AVBHT METERS	DIFF
11	952.9	9.3
12	853.9	16.1
13	952.9	14.9
14	840.2	6.4
15	302.1	18.9
16	292.8	54.0
17	247.5	10.9
18	273.0	6.7

RANGE FIRING SUMMARY

COPY 3OF 3

	1			2			3			4				
RCLAC	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	RANGE	TANGENT	BHT	AVBHT	DIFF
11	2689.1	0.34140	950.2	2710.3	0.34661	952.7	2612.1	0.36529	958.9	3548.2	0.26421	949.6	952.9	9.3
12	2570.4	0.32010	854.9	2604.8	0.32524	860.5	2495.1	0.34108	855.8	3431.2	0.24254	844.3	853.9	16.1
13	2700.1	0.33978	949.6	2719.5	0.34596	954.3	2622.9	0.35904	946.5	3559.4	0.26670	961.4	952.9	14.9
14	2544.6	0.31882	843.4	2581.0	0.31914	837.0	2469.4	0.33783	839.0	3406.3	0.24347	841.4	840.2	6.4
15	2681.9	0.09776	294.3	2707.4	0.10775	305.0	2606.0	0.11836	313.2	3539.1	0.08017	295.8	302.1	18.9
16	2725.4	0.09013	277.8	2745.6	0.11600	331.8	2648.7	0.10363	279.3	3582.6	0.07548	282.6	292.8	54.0
17	2660.0	0.09776	292.2	2689.3	0.10540	296.7	2584.8	0.11541	303.1	3516.7	0.08134	298.2	297.5	10.9
18	2668.4	0.08983	271.8	2693.3	0.09688	274.2	2592.1	0.10216	269.6	3526.9	0.07490	276.3	273.0	6.7

RCURD	AVBHT METERS	DIFF
11	952.9	9.3
12	853.9	16.1
13	952.9	14.9
14	840.2	6.4
15	302.1	18.9
16	292.8	54.0
17	297.5	10.9
18	273.0	6.7

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